UNIVERSITY OF VERMONT

Burlington, Vermont

PROGRESS REPORT NO. 3

to

National Aeronautics and Space Administration

Grant NGR 46-001-008

For Period February 1, 1966 to July 31, 1966

Dr. Clinton D. Cook

Vice President for Academic Affairs

Director of Space Science Program

August 1, 1966

TABLE OF CONTENTS

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PROGRESS REPORT NO. 3 - NASA GRANT NGR 46-001-008

Period February 1, 1966 to July 31, 1966

Introduction

The period covered by this report has seen the initiation of two new projects and the active continuation of most of the projects previously being reported. The Space Science Program made possible by the NASA Sustaining Grant continues to be most productive, particularly in the area of bioengineering, and has had a salutary effect in stimulating research in a wide variety of disciplines. A large measure of the success of the Space Science Program can be traced to the fact that the local group is essentially autonomous in the management of the grant. The flexibility of the NASA Sustaining Grant makes it possible for funds to be deployed quickly and in the most effective manner to build a strong Space Science Program.

A new project on "Absorption of Light by Wide Bandgap Semiconductors in High Electric Fields" was begun by Dr. Lloyd Lambert, Associate Professor of Electrical Engineering. Dr. Lambert's report included herein indicates that significant progress has been made on the project. It is important to note that the funds provided by the NASA Sustaining Grant made it possible for Dr. Lambert to progress to a point where the AFOSR will now provide support for three years for the project.

Another project initiated during the subject period concerned the "Mathematical Models of Physiological Processes" which is being jointly carried on by Dr. Charles Taylor, Associate Professor of Electrical Engineering and Dr. David Hill, Assistant Professor of Mathematics and Director of the Computation Center. The techniques and hardware being developed will provide for more effective analysis of physiological data by use of compartmental models.

Dr. Donald Forgays, Professor and Chairman of the Department of Psychology has made significant progress in his studies on the influence of sensory isolation. This has included refinements in the experimental setup and techniques and the completion of a series of pilot studies, and he is now prepared to initiate the actual testing of subjects. Complete details on these projects and other projects being supported by the Sustaining Grant will be found in the following progress reports submitted by the investigators.

The Sustaining Grant has now provided direct support, either in full or in part, for fourteen different research projects. This has involved directly twenty-one faculty members from eleven different academic departments in four different colleges. Five of the fourteen projects have been interdisciplinary (one involved three departments) and in several others the principal investigator depended heavily on personnel from other departments. The grant has therefore had an impact on a broad segment of the University and gives evidence of direction toward one of our prime objectives - to promote full use of our resources through interdisciplinary efforts.

In spite of the fact that the program has been in operation only eighteen months at the time of this report, research papers and reports are beginning to come forth. Copies of two papers are attached to the first copy of this report. A copy of a M.S. thesis has previously been submitted to NASA. Several other papers are in preparation or have been submitted for publication.

University of Vermont

Burlington, Vermont

NASA Sustaining Grant NGR 46-001-008

Reports of Projects

in

BIOENGINEERING

PROJECT V - UTERINE ACTIVITY AS RECORDED BY RADIO TELEMETRY

Investigator - Dr. Kenneth R. Simmons, Assistant Professor
Department of Animal and Dairy Science

Progress Report - July 31, 1966

Abstract

Radio telemetry techniques were investigated for use in recording the motility of the uterus in situ. Various aspects of electrode design and placement were also investigated.

The original ECG transmitter, designed and built by the Electrical Engineering Department of the University of Vermont, was found to be usable but not entirely satisfactory for electromyography even though it was very good for the transmission of ECG. A commercially available transmitter and receiving system was purchased, which proved to be very satisfactory.

Recordings have been made of action potentials associated with contractions of the uterine muscles. These recordings were simultaneously taken directly and via radio telemetry, and similar patterns were obtained.

A psuedopregnant rabbit and a castrate treated with 1 mg of progesterone per day gave a pattern similar to that obtained from a normal rabbit with quiescent ovaries. A castrate treated with 25 µg of estradiol benzoate had a highly motile uterus which gave mahy strong bursts of action potentials associated with peristaltic-like contractions.

Objectives

The objectives of this project were:

1. To develop radio telemetry techniques for monitoring and measuring smooth muscle activity.
2. To test improved transmitting devices for smooth muscle electromyography. These devices were to be constructed by the Electrical Engineering Department of the University of Vermont.
3. To use these devices and techniques to measure smooth muscle activity primarily in domestic animals.

Procedure of Work

The smooth muscle system to be studied was the uterus. Rabbits were used as the experimental animal. Techniques learned with rabbits were to be applied to cattle and sheep.

The areas of investigation were:

1. To adapt a transmitter, originally designed for ECG transmission, to smooth muscle myography.

2. To determine the proper type of electrodes and the best method for implanting these electrodes in the uterine myometrium.
3. To determine how long electrodes could be left in the muscle and still give an accurate interpretation of action potentials.
4. To determine the best location for electrodes, a location that would be most representative of overall uterine activity.
5. To compare results of this investigation with more conventional methods of recording uterine activity; i.e. electrical activity of individual fibers in situ or in vitro; the mechanical activity of the myometrium.
6. Then to record uterine activity, via radio telemetry, during different physiological (hormonal) conditions, as during the estrous cycle, gestation, and parturition.

Progress Report

Most previous investigations of uterine electrical activity have been carried out on isolated strips of muscle suspended in a bath. Also, most studies have dealt with the activity of single cells, by the use of intracellular electrodes. There are very few studies of the electrical activity of uterine muscle in situ so there was little information with which to compare our results. Consequently, most of our studies were conducted on the intact rabbit uterus exposed so that gross muscular activity could be observed.

The ECG transmitter that we were originally using did not prove to be satisfactory for transmitting smooth muscle electromyography. There were many problems associated with the use of this transmitter that we were unable to overcome. For example, it was impossible to eliminate noise from the recorded radio signal unless the patient was grounded. Grounding would be impossible with unrestrained animals. The design of this system required the use of a frequency meter between the receiver and the recorder. This introduced several more variables which were difficult to control, especially when dealing with an essentially unknown signal. When recording a known signal pattern such as ECG this was not such an important factor. Furthermore, temperature changes caused the signal to drift so that constant adjustment of the receiver and frequency meter was necessary. This would make the recording of signals for prolonged periods very difficult. Because of these problems we discontinued use of the ECG transmitter obtained from the Electrical Engineering Department of the University of Vermont.

Several new transmitters were obtained from the E & M Instrument Company, Houston, Texas. These new devices were designed principally for ECG, EEG, and EMG. The output of the receiver went directly to a recorder and thus eliminated the variables associated with the frequency meter of the previous system. The amplitude of the output could be controlled. These new transmitters were frequency modulated instead of amplitude modulated. The signals were strong, free of noise without grounding the patient, and did not appear to be affected by temperature. In short, they were more readily usable by biologists who do not have the services of an electronics technician.

These new transmitters were not implantable; therefore a harness would be necessary in order to attach the transmitters to an animal for long term studies. However, because they were not implantable, they could be easily accessible for battery changes.

After trying several types of electrodes we now use a silvered - copper wire (0.3 mm dia.) which is teflon coated, except for one end. This bared end was fashioned into a loop 3 mm in diameter. This loop was implated into the myometrium and sutured in place. No studies have been carried out to determine how long these electrodes can be left in place and still give an accurate interpretation of action potentials.

Various locations have been used on the uterus for implanting electrodes but the pattern of action potentials did not seem to vary much from place to place. This was because the origin of uterine contractions appeared to be randomly located throughout the length of the uterus.

In order to increase our understanding of signals received by telemetry further trials were carried out in which direct and telemetered recordings were made simultaneously from two sets of electrodes in the same approximate locations. In this way a single wave of contraction was recorded directly and via radio telemetry. Both patterns were very similar. Using this method recordings have been taken from the uterus of normal rabbits, from castrates, from castrates treated with estrogen (25 µg/day), and from castrates treated with progesterone (1 mg/day).

The data is limited because only one or two rabbits have been used for each treatment. However, as expected, the uterus from the estrogen-treated rabbit was much more motile than were those from progesterone-treated, or untreated rabbits. Bursts of action potentials, corresponding to peristaltic type waves of contraction were very strong and occurred quite often in the estrongenized uterus. Recordings of uterine motility from nontreated rabbit uteri were very similar to those of the progesterone-treated group. Examination of the ovaries of the former group showed them to be relatively quiescent, i.e., there were very few follicles present and most likely these rabbits were not in estrous at the time. One pseudopregnant rabbit gave a similar pattern.

To date no long term implantation of electrodes and recording has been attempted. However, this is the next phase of the investigation to be undertaken.

Continued work on this project should yield information on the activity of the uterus in situ. This information would be valuable in studies of sperm and ovum transport, fertilization mechanism, early embryo mortality, gestation and parturition.

Research Personnel

Dr. Kenneth R. Simmons, Principal Investigator
Paul Bruns, Technician

Other Financial Support

In addition to the NASA funds some financial support for this project has come from Hatch Act Funds, of the Agricultural Experiment Station, Project HA-144.

PROJECT VI - EFFECT ON BRAIN OF CURRENT FROM EXTERNAL ELECTRODES

Investigators - Dr. Stanley Rush, Associate Professor
Department of Electrical Engineering

Dr. Wilbert Chambers, Associate Professor
Department of Neuroanatomy

Progress Report - July 31, 1966

Abstract

This program is a study of the distribution of current in the brain resulting from the application of current through electrodes applied to the scalp and the effects of the current on brain function. The results will have application to medical problems of electrical anesthesia, electric shock therapy and to diagnosis of disorders involving the blood supply to the brain. The present initial investigations are intended to find the current distribution as a function of skull thickness, electrode placement, age, and shape of head. The methods being employed are a potential mapping of an electrolytic tank containing a human skull and arranged to simulate the geometry and conductivities of the head; a computer-aided theoretical study in which at present the scalp, skull, and brain are represented as concentric spheres; and measurements of potentials on the scalps of living subjects. By correlating the results of these three approaches we hope to obtain an accurate theoretical model to represent the head. Such a model would permit rapid calculations of current flow for any desired configuration.

In the immediate future, more accurate conductivity measurements of the tissues of the brain and scalp are planned, and more flexible theoretical models based on ellipsoids rather than spheres will be studied. In the more distant future, the same studies will be applied to laboratory animals in which the internal currents found will be introduced locally to isolate and study their effects on different anatomical regions.

Status of Work

Since the last progress report in which the completion of the instrumentation was reported, considerable data have been accumulated.

The potentials over the vertical mid-plane of the model of the head have been taken with a homogeneous interior and with a human skull. Initial computer-aided theoretical studies have been carried out to calculate these same potentials for a homogeneous sphere and a sphere containing a high resistivity shell representing the skull. The principal purpose of these studies is to determine whether the sphere, which can be analyzed theoretically, is a reasonable model for the head. The influence of skull thickness on the spherical model is also being calculated. At this point the data is all collected, but the detailed comparisons between the experimental and theoretical model data has not yet been initiated.

Further work has been performed on the statistical analysis of skull characteristics. Forty skulls have been studied in terms of their thickness variations from point to point and as a function of age at death. The youngest age

represented in the collection is thirty-five and from this age on, at least, there is little or no correlation of thickness with age or sex. Detailed photographs of skull segment cross sections are being made to show the internal skull structure which influences the resistivity. These photographs are very striking and represent an excellent view of the bone structure unfamiliar even to anatomists.

In the immediate future, current density data and total current in the brain as it depends on skull characteristics will be calculated. All of the data so far has been obtained with one particular pair of electrode placements on a particular skull. In the more distant future, the influence of electrode location and skull shape on the current densities will be obtained with the techniques devised in the initial program.

Tentatively, plans are being made to report these studies at the 19th Annual Conference on Engineering in Medicine and Biology in November to be held in San Francisco.

Research Personnel

Dr. Stanley Rush, Principal Investigator
Dr. Wilbert Chambers, Co-Investigator
Richard Blanchard, Graduate Student

Other Financial Support - None.

PROJECT VIIa - BIOENERGY ELECTRICAL SOURCES

Investigator - Dr. Wilfred Roth, Professor and Chairman
Department of Electrical Engineering

Progress Report - July 31, 1966

Abstract

A wide variety of electronic devices are implanted in animals and humans for purposes of both measurement and control of function. Measurement includes telemetering of biological data and control of function includes heart pacemakers and bladder control. All such devices presently use batteries as primary energy sources and, consequently, they all suffer from the disadvantage of having limited life.

This research project is directed toward the generation of electrical energy from the respiratory process in mammals. During the breathing process, the intrathoracic pressure varies cyclically - hence, work can be done on an auxiliary device placed in the chest. A liquid filled bladder converts intrathoracic pressure change into a linear displacement that is employed to wind a spring. The spring drives a magnetic escapement which excites a piezoelectric oscillator member. Vibration of the piezo element generates A-C electrical output which is rectified and filtered to achieve D-C power output.

A family of such energy sources is being developed.

Status of Work

The Progress Report of February 1966 briefly described the operating principles of an electromechanical device for the conversion of mechanical energy of respiration into electrical form. The period from February through July 1966 has been fruitful in verifying that the present approach is sound and that our latest embodiment shows promise for trouble free operation when implanted in an animal.

In February and March, the main spring and escapement from an alarm clock were employed to convert stored mechanical energy into oscillatory motion. A piezoelectric element coupled to the oscillating escapement successfully converted the mechanical energy into measurable electrical output in the microwatt region. Many problems were encountered due to the crudeness of the preliminary experimental components, but the results were encouraging since they validated our overall thinking and readily produced orders of magnitude improvement over the previous fluid oscillator approach.

In view of the successful results with this system, efforts were directed toward overcoming an obvious fault of the preliminary experimental rig. The usual clock escapement requires the contacting of moving parts. We felt that this is unsatisfactory for long term implantation due to the problems of wear, vibration and noise. Hence, attempts to achieve a noncontacting escapement were initiated and these have proved to be extremely successful.

A wound spring - in the final version, the spring will be kept wound by the mechanical energy of respiration - applies torque to a rotating member upon which two magnets are mounted. A magnetic flexural vibrator is mounted in close proximity to this rotor so that oscillations are induced by magnetic coupling to the rotor. The flexural element constitutes a high Q resonator closely coupled to the driving rotor and this serves as a speed governor to maintain rotation of the driving member at a constant speed regardless of applied torque over a wide range. The flexural element of the vibrator comprises a "bender" piezoelectric slab from which electrical output at the frequency of oscillation of the member is obtained. This is rectified and filtered to provide a DC voltage output.

Detailed experiments to determine the regulation characteristics of this non-contacting electromechanical escapement mechanism were conducted and measurement of power output versus physical size and the like, are presently in process.

Upon completion of further experiments on the present macro model to determine frequency stability and power output levels, designs of miniature versions for implantation in experimental animals will begin. Small main spring cartridges from self-winding wrist watches have already been procured for this purpose but miniature magnetic non-contacting escapements must still be designed and fabricated. This work will be initiated in September 1966.

Research Personnel

Dr. Wilfred Roth, Principal Investigator
One Graduate Student

Other Financial Support - None.

PROJECT VIIb - RADIOLOGICAL DATA PROCESSING - CONTRAST DEMARCATION AND MULTICOLOR PRESENTATION

Investigator - Dr. Wilfred Roth, Professor and Chairman
Department of Electrical Engineering

Progress Report - July 31, 1966

Abstract

An X-ray radiograph contains far more information than the observer is able to interpret. If the observer's ability to "read" the radiograph can be enhanced, significant progress will accrue.

Radiographs store information as shades of grey - varying from white to black - hence the color vision ability of the observer is not utilized. This research is directed toward the conversion of black and white radiographs to full color. Television scanning techniques plus electronic selection circuits are employed to convert grey levels to video signals applied to the three electron guns of conventional color TV picture tubes.

Results to date are dramatic - vivid color conversions have been obtained, but system resolution is not yet as good as the original radiographs. Quality is being upgraded and clinical evaluation will follow.

Status of Research Work

Efforts on this project since February 1966 has been directed specifically towards improvement of resolution. This involves the achievement of greater frequency response in the electronic system.

In order to overcome the limitations imposed by the commercial color TV receiver that is being used, bandwidth limiting circuitry in the receiver were by-passed and circuits of our own design were substituted. This achieved an effective improvement in the order of two octaves. The present system limitation appears to be the TV camera that is used to scan the black and white radiograph and to convert the picture into electrical video information. The frequency response of the commercial camera is now substantially below that of our color encoding circuitry so camera modification is being considered.

A basic aspect of color vision may be playing a role in subjective resolution by the observer since, even with the improved frequency response, resolution under black and white display seems to be better than with color display. It has not been possible, to date, to separate the subjective visual response of the observer from the bandwidth limitations of the TV camera. Black and white high frequency signals do appear as shades of grey variations even though the variations are greatly reduced over those in the original radiograph. However, when these grey signal variations are converted into color, the variations appear as beam current variations in only one of the three color guns. Hence, the high freqnency signals,

if introduced from the camera with low amplitude, do not modulate all three guns and the subjective color rendition is greatly reduced.

A system of logical gates is presently being devised to cope with this problem since we wish to achieve as high a resolution as possible with the auxiliary electronic apparatus before redesigning our present camera or purchasing a more expensive higher quality unit.

Research efforts in the Fall of 1966 will continue with efforts to improve the resolution of detail and color rendition. In addition, the mixing of black and white signals with the color signals and data processing to emphasize signal gradients will be incorporated.

Research Personnel

Dr. Wilfred Roth, Principal Investigator
Dinesh Tewarson, Graduate Research Assistant

Other Financial Support - None.

University of Vermont

Burlington, Vermont

NASA Sustaining Grant NGR 46-001-008

Reports of Projects

in

CHEMISTRY

PROJECT XII - CALCULATIONAL AND EXPERIMENTAL ASPECTS OF ANTROPY DETERMINATIONS

Investigator - Dr. Claus A. Wulff, Assistant Professor
Department of Chemistry

Progress Report - July 31, 1966

Abstract

There are, perhaps, as many definitions of the entropy concept as there are textbooks of thermodynamics and statistical mechanics. It is common experience that when ice and hot water are mixed in a thermos jar the final state will be one of uniformly tepid water. It is equally true that when two different gases are placed in the same vessel a uniform gas mixture (air, if the mixture is 80% nitrogen and 20% oxygen) results. On the basis of the conservation of energy principle alone, neither of these processes can be predicted; nor would there be any restrictions on the reverse processes - the spontaneous conversion of tepid water to ice and hot water, or the unmixing of air to give nitrogen and oxygen. But yet, naturally occuring processes are known to be unidirectional, or as Bridgman[1] has stated: "......The direction of the sequence of changes which occurs is not capricious, but if a particular sequence starts or runs at all it will run in a unique direction....." It is to deal with this problem - a quantitative predictor of the direction and extent of a chemical or physical change in state - that the entropy concept has been developed in thermodynamics (for macroscopic systems such as the melting of ice) and in statistical mechanics (for microscopic or molecular systems such as the mixing of gases). Entropy changes for reactive systems can be deduced by thermodynamic and/or statistical arguments from physical measurements on the pure components that form the reactive system; and the calculated entropy changes can then be used to predict the direction and extent of the pertinent reaction. For many systems, including those of biological importance, the experimental data are difficult to obtain. This research program is concerned with the development of methods of entropy estimation from measurements on compounds related to those of interest, and from statistical calculations.

Introduction

In contrast with the period discussed in the last progress report the major effort during this semester has been devoted to the experimental portion of the program. Sections (b) and (c) of the Experimental review below make reference to a solution calorimeter. While the construction and calibration of this apparatus was not directly supported by NASA funds, the calorimeter will be used in the NASA experimental program. A report of its construction is appended.

During this period additional financial support for the project was obtained from the Research Corporation in the form of a Frederick Gardner Cottrell grant for $6,000.

1. P. W. Bridgman, "The Nature of Thermodynamics", Harper and Row, New York, 1961.

Calculational

(a) The estimation of inorganic entropies: This project has been completed. A scheme for estimating the entropies of simple inorganic compounds has been outlined, and tested by comparison of calculated and experimental entropies for metal halides and sulfates. The root-mean-square deviation for the entropies of twenty-two monovalent halides is 0.2 cal/mole ^{o}K. The comparable value using the estimation method proposed by Latimer (1) is 1.2 cal/mole ^{o}K.

(b) The entropies of aqueous ions: The paper describing the thermochemical paths to the entropies of the aqueous Zn(II), Cd(II), Hg(I), and Hg(II) ions was presented at the national meeting of the American Chemical Society. A similar set of calculations for the aqueous Cu(II), Co(II), Ni(II), and Mn(II) ions has been started, making use of new data for Co(II) and Ni(II). A related experimental program in this laboratory will provide data for Cu(II) ion.

(c) The nature of the transition in 3-azabicyclo 3.2.2 nonane: A solid-solid transition has been found for 3-azabicyclo 3.2.2 nonane at 24.9^{o}C(2). A stochastic model to account for the nature of the transition and the magnitude of its associated entropy increment is being developed. This model includes a postulated change in the symmetry of the N-H vibration. Temperature dependent IR and NMR studies are being tried to test this postulate.

Experimental

(a) The entropies of the aqueous $CaOH^{+}$ and $BaOH^{+}$ ions: Mr. John Lerbscher has completed a series of measurements on the concentration dependent pH of solutions of $Ba(OH)_2$ and $Ca(OH)_2$. Both of these materials are only slightly soluble, and their saturated solutions are extremely susceptible to carbonate formation in the presence of air. An all-glass handling system in which the solutions can be prepared, stored, and transferred was constructed. Measurements of pH were made with the Corning Model 12 pH Meter for solutions diluted from saturation to 10^{-4} molal. Duplicate determinations made several weeks apart were reproducible within the limits of the instrumentation (0.004 pH) - giving an indication of the stability of the original solutions.

Preliminary conclusions drawn from Mr. Lerbscher's data indicate that the low value recently reported (3) for the dissociation constant of $BaOH^{+}$(aq) is probably wrong, and that both $BaOH^{+}$(aq) and $CaOH^{+}$(aq) are "almost strong" electrolytes. Earlier this year several electrodes sensitive to metal ion activities (in the manner that a pH electrode is sensitive to hydrogen ion activity) became available commercially. Typical dissociation constant evaluations from pH determinations involve the estimation of an absolute activity coefficient. Use of a metal sensitive electrode will reduce the problem to the estimation of an activity coefficient ratio, and presumably will allow greater precision in the evaluation of dissociation constants. A calcium sensitive electrode has been ordered and will be so used. Such

equilibrium data will then be combined with extant enthalpy data to evaulate the partial molal entropy for $CaOH^+(aq)$.

(b) The entropy of the aqueous fluosilicate ion: Prior to 1962 the only entropy estimates for fluosilicate ion, SiF_6^{-2}, were those of Latimer (1), -12 cal/mole ^oK, and Ryss (4), 29 cal/mole ^oK. This author, as part of his doctoral research, determined the absolute entropy of $(NH_4)_2SiF_6$ and collected thermochemical data from which an entropy of 30 $\pm$ 10 cal/mole ^oK could be calculated for the $SiF_6^{-2}(aq)$ ion. The principle problem encountered was related to the hydrolysis of the anion to give several species presumed to be of the type $SiF_n(OH)_{6-n}^{-2}(aq)$. Various hydrolysis schemes have been considered - most of them containing a slow rate determining step. Mr. Lerbscher has prepared a sample of $(NH_4)_2SiF_6(c)$ and has characterized this material by X-ray diffraction and by chemical analysis. A stock solution of this material has been prepared and periodic pH measurements, as a function of concentration, have been started. It is anticipated that a slow hydrolysis step will be evidenced by a change in the concentration dependence of pH over the course of several months. In addition to the hydrolysis of the anion, one must consider the hydrolysis of the $NH_4^+(aq)$ ion. {The potassium salt is unfortunately insoluble; and is, indeed, the basis of a gravimetric determination of fluosilicates}. To determine the ammonium ion's contribution to the hydrolysis, Mr. Lerbscher is making pH measurements on solutions of $(NH_4)_2SO_4$ over the same concentration range.

The principle purpose of these hydrolysis measurements is to obtain a guide for the proper extrapolation of heat of solution measurements to standard state conditions. Heats of solution, both in pure water and dilute acid, will be made in the existing calorimeter. These data will then be combined with solubility results to evaluate the partial molal entropy of $SiF_6^{-2}(aq)$.

(c) The thermodynamics of transition in 3-azabicyclo [3.2.2] nonane: As is fairly common for compounds whose molecules possess a high degree of symmetry, 3-azabicyclo [3.2.2] nonane, AZBN, undergoes a solid-solid transition prior to fusion. Within the framework of theory concerning plastic or "embific" crystals, the transition is considered to be between a low-temperature or ordered crystal, AZBN (II), and a high-temperature disordered, AZBN(I), modification. For AZBN the transition occurs at 24.9°C(2) - making it conveniently accessible to several types of calorimetry. The thermodynamics of transition have been studied by adiabatic calorimetry.

Miss Albertine Meymerian, an undergraduate research participant, has recently joined the group and has undertaken to investigate the thermodynamics of this transition by solution calorimetry. The difference in heats of solution of AZBN(I) and AZBN(II) in a common solvent is simply the enthalpy increment for the reaction AZBN(II) = AZBN(I). Miss Meymerian has purified a commercial sample of AZBN by successive vacuum sublimations, and has prepared a sample of AZBN(II) by annealing at liquid nitrogen temperatures. She has, furthermore, completed simple solubility tests leading to the choice of benzene for the calorimetric solvent.

The derived heat and entropy of transition will provide a check on the values obtained by adiabatic calorimetry. Since the transition is assumed to be of the order-disorder type, it would be interesting to determine the entropy changes for the reactions

$$\text{AZBN(I and II)} = \text{AZBN(solution)} \quad \Delta S_I, \Delta S_{II}.$$

Since the solution species is presumably "highly disordered" one would expect ΔS_I to be smaller than ΔS_{II}. To determine either quantity the activity of AZBN in its saturated benzene solution must be determined as a function of temperature. Such determinations are being reserved until the heat of solution measurements have been completed and an estimate of the non-ideality of the AZBN-benzene solutions can be made.

(d) The construction of the cryostat The cryostat blueprints have been completed, revised, and reviewed by Professor Edgar F. Westrum, Jr. (University of Michigan). Duplication of the prints (11 prints, each 4' by 3') have proved difficult but is now being done in Ann Arbor. This author will soon visit Ann Arbor, after the Calorimetry Conference, to discuss the economics of construction. A platinum resistance thermometer has been purchased. Discussions have been held with field representatives of the Leeds and Northrup, and Honeywell companies concerning the needed instrumentation.

Research Personnel

Dr. Claus A. Wulff, Principal Investigator
John Lerbscher, Graduate Student
Albertine Meymerian, Undergraduate Research Participant

Other Financial Support

Petroleum Research Fund - $2,000
Research Corporation - $6,000

Publications - None.

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University of Vermont

Burlington, Vermont

NASA Sustaining Grant NGR 46-001-008

Reports of Projects

in

COMPUTATIONAL TECHNIQUES AS APPLIED TO THE MEDICAL FIELD

PROJECT VIII - COMPUTER-ASSISTED EVALUATION OF INFORMATION CONTENT OF LABORATORY MEASUREMENTS

Investigators - Dr. Rex D. Couch, Assistant Professor
Department of Pathology

Dr. David C. Lai, Assistant Professor
Department of Electrical Engineering

Progress Report - July 31, 1966

Abstract

The objective of this project is to define the amount of inference or information in laboratory tests in various physiologic states. The system of measurement is based upon probability theory. Initially, the measure has been used to provide the information in one laboratory measurement and one physiologic state - this is the one-dimensional case. Now the two-dimensional approach is being developed - the information present in two test results for any number of disease combinations. The ultimate goal of the project is the construction of an n-dimensional system (which, in the case of Medicine, would be a diagnostic system) for pattern recognition. This system will utilize unsupervised machine learning as well as probability theory.

Status of Work

There has been increased activity and progress in this project over the year. The input systems are fully tested, editing programs are operational, and retrieval programs have provided a number of new approaches now being developed. As was expected, the use of traditional gaussian statistical methods in the analysis of data from hospitalized patients has not provided reliable measures of normal values for laboratory test results. A visual plot output for frequency distribution of test values has been added to the matrix output table in Clinical Chemist Chemistry. The retrieval program for Bacteriology is now being developed in consultation with the Infectious Disease Unit in the Department of Medicine. The alleged variation in "normal values" for differential leukocyte counts has been documented by the Hematology limits evaluation program.

The project in the feasibility of battery testing of all hospitalized patients is nearing completion and will be submitted for publication this summer. This project has been extremely useful as a mechanism for stimulating the interest of other members of the Department of Pathology in the computer program.

Because of the success of the summer student programming efforts last year, we now have four student programmers. Two are translating existing programs to IBM 1130 FORTRAN language, one is writing a program for calculation of normal values by a non-parametric method developed by Dr. Lai, and the other is writing quality control research programs in conjunction with a student in Medical Technology.

The series of studies that will lead to a pattern recognition system are progressing well. A "one-dimensional" approach has yielded a measure that we call the Information Index, which calculates the amount of information, or inference, that single test contains with reference to a single disease or group of diseases. The results of this study are being presented at the Rochester Conference on DATA Acquisition on July 26, and in the Scientific Assembly of the American Society of Clinical Pathologists on September 21. The program for two-dimensional analysis of the information in multiple tests in multiple diseases is nearing completion.

The transducer for transmission of signals from an automatic analyzer directly to the keypunch is now finished and will be installed in the next few weeks. A related project on development of instruments and methods for isotope dilution technics in Biochemistry is well underway.

The IBM 1130 computer is scheduled for delivery in November, 1966, and site planning and program translation for the installation are proceeding. The development of this installation and of the project in general has generated considerable interest of the faculty in the College of Medicine, and personnel associated with this project have served as informal "consultants" for development of projects in Radiotherapy, Pathology, Obstetrics and Gynecology, and Surgery. The relationship with the Medical Computer Program at the University of Missouri has continued and a joint study of cyclic changes in iodine metabolism is in progress.

This project has become more closely allied with the University Computation Center in the past year and the cooperative arrangements and consultation have been most beneficial.

Research Personnel

Dr. Rex D. Couch, Principal Investigator
Dr. David C. Lai, Co-Investigator
Edmund H. Shephard, Programmer (to June 10, 1966)
Roderick Halstead (from Sept. 1, 1966)
Veronica C. Evering
John C. Abajian, Student Programming Trainee
Paula Flynn, Student Programming Trainee
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Other Financial Support

NIH General Research Support Grant
Edward C. Andrews, Associate Dean, College of Medicine - $2,140.00

PROJECT XIV - MATHEMATICAL MODELS OF PHYSIOLOGICAL PROCESSES

Investigators- Charles F. Taylor, Associate Professor
Department of Electrical Engineering

Dr. David B. Hill, Assistant Professor
Department of Mathematics

Abstract

The object of this study is to develop a hybrid computer to aid in the development of Mathematical Models for Physiological Systems. In particular, this investigation has been concerned with systems in which it is reasonable to suppose that the observations represent sums of decaying exponential functions.

Progress toward this objective has been achieved in two areas. First, mathematical techniques have been developed which facilitate the analog implementation of required computations. Rather than attempting to minimize the error functional in the space of the physiological parameters this procedure is carried out in a "mathematical parameter" space. These mathematical parameters are in fact the poles and zeros of the system transfer function. This technique allows the easy computation of the necessary gradient components in the analog section.

Secondly, significant new hardware has been developed enabling the construction of the analog section at moderate cost. The basic building block is an all solid state logically controlled operational amplifer with an associated comparator. This device can be used universally in special purpose computers to perform, sample and hold, integration, accumulation and table look-up operations.

Status of Work

The primary objective of this project is to develop a hybrid device for the analysis of Physiological data by means of the "Compartmental Model" technique. Progress toward this objective has been made in two distinct areas. First, the method implementing a solution, utilizing logically controlled analog hardware to a great extent, has been developed. This technique will allow for extremely rapid iteration, producing up to ten complete iterations per second. Secondly, significant new hardware has been developed, enabling the construction of the analog section at moderate cost. This device promises to be of value in a wide range of applications and has been incorporated by one of the investigators (Dr. Taylor) in a special purpose computer for on-line pulmonary function studies.

Although the method of solution outlined below applies in general to any number of compartments, the investigators have concerned themselves to the present with the solution of a 2 compartment model.

The basis for the solution procedure is the fact that, subject to certain regularlity conditions,

$$\frac{\partial}{\partial \pi_j} L^{-1} f(s, \pi_1, \ldots, \pi_n) = L^{-1} \frac{\partial}{\partial \pi_j} f(s, \pi_1, \ldots, \pi_n)$$

where L^{-1} indicates the inverse Laplace Transform.

Thus in computing the gradient of the cost function:

$$\Gamma = \sum_{i=1}^{n} \left(x(t_i) - y(t_i, \pi_1, \ldots, \pi_n) \right)^2$$

where $x(t_i)$ are the actual observations and $y(t_i, \pi_1, \ldots, \pi_n)$ are the predicted values at time t_i with parameters $\pi_1, \ldots, \pi_n$, one can generate $y(s, \pi_1, \ldots, \pi_n)$, compute its partials with respect to the parameters and thus generate $\nabla_\pi y(t, \pi_1, \ldots, \pi_n)$ in the time domain.
In Compartmental Models, where y(t) represents the amount of tracer in a compartment at time t, y(s) is given by:

$$y(s) = q_o \frac{\left[s^m + a_1 s^{m-1} + \ldots + a_m \right]}{\left[s^n + b_1 s^{n-1} + \ldots + b_n \right]}$$

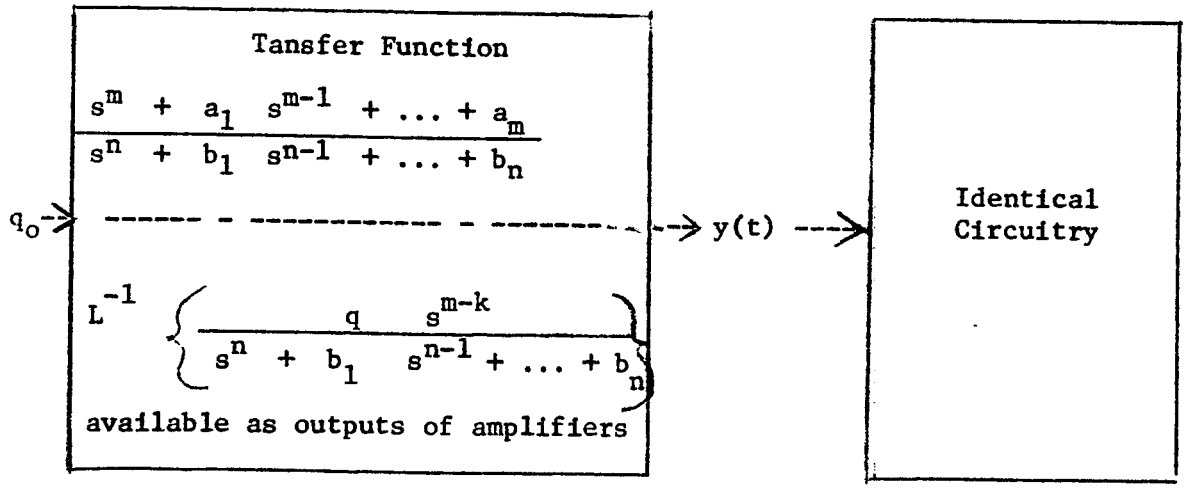
where the a's and b's are known functions of the physiological parameters of interest. Thus

$$\frac{\partial y(t)}{\partial b_j} = L^{-1} \left\{ -y(s) \frac{s^{n-j}}{\left[s^n + b_1 s^{n-1} + \ldots + b_n \right]} \right\}$$

and

$$\frac{\partial y(t)}{\partial a_k} = L^{-1} \left\{ \frac{q_o s^{m-k}}{\left[s^n + b_1 s^{n-1} + \ldots + b_n \right]} \right\}$$

In order to carry out the solution in the simpliest possible way, it was decided to minimize Γ in the space of the a_i and b_j rather than in the physiological parameter space. This technique allows us to generate $\nabla\Gamma$ in a simple fashion as outlined below:



q_o is input to the first circuit and y(t) is generated continously. Furthermore, as indicated, $\frac{\partial y(t)}{\partial a_k}$ is continously available as intermediate output in the first circuit. By using y(t) as the input to the second package, (referring to the form of $\frac{\partial y}{\partial b_j}$ above), $\frac{\partial y(t)}{\partial b_j}$ will be continously generated in circuit #2.

Thus y(t) and ∇ y(t, a_1, ..., a_m, b_1,..., b_n) are generated in parallel. At time t_1 all amplifiers are switched to hold by a camparator circuit, $x(t_1)$ is entered and the quantities $-2\left[x(t_1) - y(t_1)\right] \frac{\partial y(t_1)}{\partial a_i}$, i = 1, ..., m and $-2\left[x(t_1) - y(t_1)\right] \cdot \frac{\partial y(t_1)}{\partial b_j}$, j = 1, ..., n are entered into accumulators. The computation then proceeds to time t_2 and so on. At time t_n the components of $\nabla\Gamma$ are stored in the accumulators. These are converted A to D and entered into a digital section.

Initially it was felt that an experienced investigator might be able to enter a step size, change the parameters by this amount in the gradient direction and arrive at a stationary point ($\nabla\Gamma = 0$) more rapidly than by using a linearization scheme. Experience indicated that this is not the case. Thus future plans call for the addition of a third identical circuit, which by sequential sampling of the outputs of #1 and 2 will compute the second partials of Γ. These will be entered along with $\nabla\Gamma$ into a digital computer and Gauss-Newton techniques applied to determine the new parameter values. It is proposed to have the new values entered manually into the hybrid section in order to keep hardware costs to a minimum.

The basic building block of the special purpose computer portion of the hybrid realization is an all solid state logically controlled operational amplifier and an associated comparitor. This device is used universally throughout the special purpose computer in performing sample and hold, integration, accumulation, table look-up analog memory and a novel table look-up multiplication operation.

Research Personnel

Dr. Charles F. Taylor, Principal Investigator
Dr. David B. Hill, Co-Investigator

Other Financial Support - None.

University of Vermont

Burlington, Vermont

NASA Sustaining Grant NGR 46-001-008

Reports of Projects

in

ENGINEERING

PROJECT III - NUMERICAL METHOD FOR DETERMINING THE RESIDUAL STRESSES RESULTING FROM SUDDEN HEATING OF THE INNER SURFACE OF A SHORT HOLLOW CYLINDER

Investigator - Howard Duchacek, Associate Professor
Department of Mechanical Engineering

Progress Report - July 31, 1966

Abstract

If the inside surface of a short hollow cylinder is heated somewhat suddenly, the material near the inside surface will expand and be forced generally into compression, and consequently the material near the outer surface will generally be stressed in tension. This condition usually occurs in the first few seconds of the heating period, and sometimes results in rupture of the material. The phenomena is usually accompanied by an elastic-plastic behavior of the material, and since the conditions change with time, the theoretical analysis is difficult. A numerical solution is attempted using a digital computer wherein the interaction of many thin cylindrical rings within the cylinder during several short intervals of time enables a determination of the stresses and strains, which vary with time, across the thickness of the cylinder. In the experimental portion of the program several temperatures and also the deformation of the outside diameter of the cylinder over the heating and cooling period are measured. The numerical and the experimental data are to be correlated.

Objectives

1. It is proposed that the numerical method for determining thermal stresses involving plastic flow in a constrained flat plate be extended so that a computer program will be written to determine residual stress which result from suddenly heating the inner surface of a short hollow cylinder.

2. It is proposed that a method be determined to specify the temperature distribution in a cylindrical ring, the temperature of the inside surface of which is a non-linear function of time.

3. It is proposed that an experimental program be conducted to determine the temperature, and strain during the heating cycle and the residual strain upon return to ambient temperature.

First Objective

A computer program has been written according to the method prescribed under "First Objective" of the February 7, 1966 Semi-Annual Report. Briefly, a cylindrical ring is divided into many shells, the temperature and properties of each is known at any time instant. Using deformation theory, the plastic strain (if any) is calculated on each shell at a particular time instant, and new sizes of the cold shells are calculated. The new size shells are stressed and exposed to new temperatures so that they are compatible (the outside diameter of one equals the inside diameter of the next outer one). The method is continued for many time instants until ambient temperature is attained and

residual stresses and strains exist.

The program for the first time instant was written prior to the February 7 report. The program for the additional time instants has since been written and has been run with data provided from welding research data. The computer results obtained do correlate very well with the welding results. Data for pressed and sintered tungsten rings will be inserted into the program and those results will be correlated with results of the experimental program.

Second Objective

Experimental work continues on determination of heat flux to the inside surface of the rings. Effort here was reduced so as to concentrate on the computer program described under "First Objective." The problem of attaching thermocouples to the end surface of the cylindrical pressed and sintered tungsten rings has been solved with use of a capacitor discharge circuit that welds the very small chromel-alumel thermocouples to the tungsten rings. Further effort to determine temperature distribution and heat flux will continue in the immediate future.

Third Objective

Pressed and sintered tungsten rings have been received for this part of the experimental program. The strain measuring system has been constructed. This consists of a heavy cylindrical ring which contains four linear-variable-differential transformers which transmit deformation signals to a sensitive recording device (Visicorder). Deformations from the outside surface of the cylindrical rings will be transmitted through high temperature sensing points (recrystallized alumina) so that time, temperatures and deformations will all be recorded on a single, relatively trouble-free device.

Summary

Generally, the computer solution has received most attention during the previous five months and that program is now available. The strain measuring device has also been constructed and is ready for use. Experimental and computer results will be obtained this summer for correlation and analysis of stress-strain-time results this fall. The completion date of February 1, 1967 appears to be reasonable.

Research Personnel

Research on the above project began in April, 1965 with the assignment of Prof. Howard Duchacek to the project for one-quarter of his academic program for the months of April and May. During the Summer of 1965 graduate students, Timothy L. Brosseau and Robert B. Lee joined the project for 13 weeks of the summer and were supervised by Professor Duchacek on a one-quarter of one-ninth basis. From September 1, 1965 to February 1, 1966 the graduate students were on a half-time academic basis by Professor Erling Chamberlain, also on a one-quarter time basis. From February 1, 1966 to June 1, 1966 Prof. Duchacek was on a quarter-time basis and the graduate students were on half-time. During the Summer of 1966 the graduate students will devote 13 weeks each to the project, and Prof. Duchacek will devote two months.

Other Financial Support

Date	Amount	Agency
August 1962 - September 1963	$22,240	Naval Research Laboratory
October 1963-September 1964	25,157	Naval Research Laboratory
October 1964-October 1966	39,988	Naval Research Laboratory

Reports on Subject Research

1. H. Duchacek and T. L. Viau.
"A correlation of Temperature Distribution Parameters Concerned with Thermal Shock." June, 1962, Progress report to NRL.

2. H. Duchacek and T. L. Viau
"A Computer Program to Determine Thermal Stress Involving Plastic Flow." August 1962, Progress report to NRL.

3. H. Duchacek and T. L. Viau.
"Investigation of Thermal Shock Characteristics of some Rocket Nozzle Materials." September, 1963, Progress report to NRL.

4. H. Duchacek, D. P. Fay, and T. L. Viau.
"Reduction of Severity of Thermal Shock Stress of a Clamped Plate by Previous Sudden Heating of the Same Surface." May 30, 1964, Report to NRL.

5. H. Duchacek, D. P. Fay, and T. L. Viau.
"A Computational Method Involving the Two Dimensional Elastic-Plastic Assumption to Determine Residual Stresses Resulting from Welding Moderately Thick Plates." June 30, 1964, Progress report to NRL.

6. H. Duchacek, D. P. Fay, and E. W. Chamberlain.
"A Numerical Computer Program to Determine Thermal Stresses and Strains in Thin Elastic Disks." June 10, 1965, Progress report to NRL.

7. H. Duchacek, T. L. Brosseau, and R. B. Lee.
"A Numerical Computation of Thermal and Residual Stresses in a Disk in the Elastic-Plastic Mode Resulting from a Suddenly Applied Centrally Located Heat Source." March 31, 1966, Progress report to NRL.

PROJECT XIII - ABSORPTION OF LIGHT BY WIDE BANDGAP SEMICONDUCTORS IN HIGH ELECTRIC FIELDS

Investigator - Dr. Lloyd M. Lambert, Associate Professor
Department of Electrical Engineering

Progress Report - July 31, 1966

Abstract

The absorption of light at frequencies corresponding to energies for valence band to conduction band transitions in wide bandgap semiconductors gives useful information with regard to the nature of the bands and the type of transitions. If the electron can achieve large momentum values due to the large electric field and small scattering probability, then quantization of the conduction band should be observable. This particular experiment is "critical" inasmuch as our quantum mechanical understanding of band structure rests on a framework of mathematics which predicts such quantization. To observe this effect experimentally would provide satisfying confirmation of our mathematical treatment of band structure in semiconductors especially with regard to interband transitions.

Introduction

The work during this report period was primarily concerned with planning, purchasing, and checking out the various items of laboratory equipment necessary to the experimental program. Some theoretical study of the problem was conducted and some interesting new results were noted by other investigators which can be investigated experimentally within the scope of the program.

Experimental Work

The experimental work can be best tabulated with regard to area of use as:

1. Lapping, Polishing and Etching. The precision lapping equipment was set up in the lab area and checked out. A fume hood was purchased and is being installed over the sink with venting through existing ducts to the roof. This hood is required for etching GaAs with the standard bromine etch. Precision wafer measuring equipment was purchased and checked out. The necessary chemicals and associated containers were purchased and set up in the lab area.

2. Sample Fabrication. The NESA glass has been obtained and will be etched after the installation of the fume hood so that indium contact rings can be evaporated. Mylar is to be used as the dielectric although other materials are under investigation. Semi-insulating GaAs has been obtained from Services Electronic Research Laboratory, Baldock, England for use in this work. The material will be X-ray oriented along the (100) and (111) planes and wafered in the near future.

3. Spectrophotometric Measurement. The Cary 14R was ordered and is scheduled to be installed in September 1966. The dewar assembly has been rewired and

vacuum checked for use in the spectrophotometer. A multipurpose vacuum system, purchased under a NSF Grant, has been modified for use with the dewar.

4. Electronic Measurement. The oscilloscope and high voltage probe have been obtained for use in aligning and measuring the high electric field pulses used. Work is continuing on a revised pulser system needed to reach 5×10^5 volts per cm.

Theoretical Work

A recent paper by Duke and Alferieff[1] on a solvable model of a hydrogenic system in a strong electric field with particular emphasis on optical absorption in semiconductors cites some of my previous results. However, since my lowest field value was 5.83×10^3 volts per cm., the most interesting portion of the absorption response as predicted by this theory, can only be observed below 1.7×10^3 volts per cm. The general trend of the higher field results indicate a lowering of the continuum edge, as measured by optical absorption, due to electron-hole, Coulomb interaction. It will be interesting to check the theory at the earliest possible time to see if the large exciton peak at 0.5 ev below the the band edge really exists and can be removed with an increase in electric field.

Additional work has been done on examining the effect of the low temperature on the electron mobility. Since in the current theory of ionized impurity scattering centers, the Coulomb field is cut off by screening at finite temperatures. The apparent effect of lowering the temperature is to increase the mobility as the phonons disappear and then to decrease the mobility due to small angle scattering by the ionized impurity centers as the temperature is reduced further. The ionized impurity centers are due to the oxygen necessary to convert semiconducting to the semi-insulating type. Not only is the mobility decreased by the ionized scattering but also this small angle scattering tends to coalesce the Wannier levels to a continuum in competition with the quantizing of the electric field.

A complete calculation of these competing phenomena will be completed in the near future.

Future Plans

The main item of interest, the spectrophotometer, will be installed in September. After check out, the sample preparation and preliminary tests can be conducted. Verification of the theory of Duke and Alferieff[1] can be accomplished shortly thereafter. Work is continuing on the high voltage pulser for the quantization research and should be completed by the end of the year.

Research Personnel

Lloyd M. Lambert, Principal Investigator

[1] C. B. Duke and M. E. Alferieff, Phys. Rev. 145, 583 (1966).

Other Financial Support

1. NSF Grant No. GU-1505; 1 Nov. 1965 to 31 Oct. 1966 - for purchase of vacuum evaporator and associate equipment for the fabrication of samples.

2. AFOSR Grant; 1 July 1966 to 30 June 1969 - for further research into quantization of the continuum states in high electric fields.

University of Vermont

Burlington, Vermont

NASA SUSTAINING GRANT NGR 46-001-008

Report of Project

in

PSYCHOLOGY

PROJECT IV - INDIVIDUAL DIFFERENCES IN THE INFLUENCE OF SENSORY ISOLATION UPON INTELLECTUAL, EMOTIONAL, AND PHYSIOLOGICAL FUNCTIONS

Investigator: Donald G. Forgays, Professor and Chairman
Department of Psychology

Progress Report - July 31, 1966

Abstract

Persons subject to sensory restriction or isolation, as in underwater exploration, early warning radar observation work, or in space flight, frequently report perceptual distertion, problem solving and memory difficulties, and the like, after only brief periods of isolation. This study attempts to investigate the individual differences in susceptibility to such effects and then to study the possible amelioration of such distortions through selective inputs during the isolatory period. Initial effort in this study has been spent in producing an adequate and well controlled isolation; underwater isolation with supplied air breathing was chosen as the optimal experimental environment. A great deal of time and effort was spent in effecting adequate techniques for physiological and psychological measurement underwater, since both types of measures are important in this project. The study is at the stage now where subjects are exposed to the isolatory experience and their responses to it are being observed systematically. The principal variables of the study are four: a) individual differences -- these are measured differences in the subjects in terms of personality dimensions and physiological status; b) time of isolation -- this will vary from three to six hours initially; c) reporting time -- the subject will either be allowed to report any phenomena as they occur in isolation or will report only upon exit from the tank; and d) sensory input -- subjects will be assigned to one of three conditions, the first provides for as complete an absence of sensory input in isolation as possible, the second provides unstructured auditory and visual signals to some subjects, and the third provides highly organized visual and auditory signals. Each of these parameters will be studied individually and as interaction variables.

Literature Search and Technical Problems of Subject Immersion

This study has been underway for approximately fourteen months. As indicated in the last progress report (February 1, 1966), attention has been directed chiefly to two tasks -- literature search and technical problems of subject immersion. These tasks have been largely completed as indicated below and pilot immersions have been undertaken.

1. The review of the past literature has been completed and contemporary literature is constantly monitored so that the bibliography remains up-to-date. To date some 350 relevant titles have been assembled. An article reflecting this review is underway and it is expected that it will be submitted for publication in the next reporting period. As suggested in earlier progress reports, there have been few isolation studies in which adequate controls have been employed or, indeed, in which systematic variation of conditions was effected. For example, subject differences has not been a

variable studies to any extent. Moreover, variation in depth of isolation, especially with a no isolation condition, has not been effected systematically. Duration of effect and possible amelioration of effects has not been studied. Many of these lacunae possibly reflect the great difficulty in achieving adequate base conditions of isolation. The present study attempts to investigate each of these variables under appropriate conditions.

2. Technical problems of subject immersion have continued to occupy much of our attention, with their resolution occurring in the past week or so.

   a) Where we had relied upon gravity heating of the immersion water (through large radiators in the isolation room), this procedure was replaced by a large coiled immersion heater in the tank itself. This has been custom fabricated, is now installed, and appears to be functioning properly. This will guarantee us constant water temperature at body heat.
   b) A filtering system for the water has been installed and the water itself is now treated chemically. Testing indicates that the water environment is medically acceptable for long term immersions (up to a dozen hours or so).
   c) The two-way communication system between subject and experimenter has been installed and is functioning well. This allows us the possibility, which has now been built into the design of the experiment, of producing a large variety of auditory signals (from pure unstructured tones to structured patterns) and impinging these upon the subject in the tank. The relation between such signals and perceptual changes in the subject or amelioration thereof will now be studied.
   d) Recording of physiological measures (e.g., EKG, EEG, GSR, etc.) taken underwater has been worked on to a considerable extent. Our electrical engineering consultant has effected appropriate grounding and shielding techniques so that these records appear to be as adequate as those obtained under dry conditions. In this regard, we have added a fourth amplifier to our physiograph so that we can monitor signals on a shorter time scale. It is now planned to monitor EKG, GSR, four EEG loci, respiration, and pulse. With four amplifiers, we can record half of these signals at any one moment in time. Respiration and EKG will be constantly monitored so we will be able to record each of the other measures about 40% of the total time of immersion.
   e) Because of the urinary problems referred to in our last report, male subjects only will be studied initially. Elimination bags have been obtained and the urine will be subjected to analysis as part of our physiological studies. Cooperation of the Medical College has been arranged in this regard.
   f) As reported earlier, we have immersed approximately ten pilot subjects to date for periods up to one hour, plus. This has been done largely to test out the equipment, and experimenters and their colleagues have been employed as subjects. On this basis, it is now felt that most technical problems have been dealt with effectively and that the full-scale study can now begin.
   g) The personality indices have been chosen as part of the study of individual differences; they include the following:

      1. The Cattell 16 PF Personality Test.
      2. The Minnesota Multiphasic Personality Inventory.
      3. The Edwards Personal Preference Scale.
      4. The Morris Scale: Ways to Live.

h) The initial group of subjects for the experiment has been recruited. Ten have been subjected to complete physical examination by our medical consultant and are now undergoing the personality testing phase of the project.

i) Revised procedure now calls for a preliminary immersion of each subject for approximately 15 minutes for the purpose of acclimating him to the breathing apparatus and the underwater environment. This is followed within a few days by the longer experimental immersion. This step was indicated by our preliminary studies which suggested that the newness of the situation, especially the problem of aided breathing underwater, captured the full attention of the immersed person to the extent of preventing his relaxation for a considerable period of time. The short indoctrinational trial appears to be sufficient to prevent inhibitory processes from operating, at least to any considerable extent.

j) We have also modified the condition of subject placement in the isolation tank. Previously we had simply suspended the subject by the air hose--and electrical recording--harness in the tank and used a weight belt to counteract body buoyancy. This had led to the difficulty of a good deal of body attitude. To correct this situation, we have installed a summer lounge chair in the bottom of the tank. The subject is initially seated in the chair and a a seat belt loosely fastened. We have found that the subject will float out of the chair (natural buoyancy) and be held suspended by the seat belt; this latter pressure adapts-out within a few minutes. We anticipate no further problems of maintaining appropriate body attitude in the tank.

k) As indicated in h) above, subjects for initial full testing have been recruited and have already begun the experimental program. It is anticipated that approximately 50 subjects will be tested by the beginning of next year.

l) There have been minor changes in the overall design of the study. The principal parameters to be varied include:

1. report time Essentially two conditions here:

   a) Subject reports any phenomena as they occur.
   b) Subject reports experiences in the tank only upon exit from the tank.

2. sensory input Essentially three conditions here:

   a) Total absence of input, or as close to this state as the tank isolation can provide.
   b) Input of pure and unorganized auditory and visual signals.
   c) Input of highly organized visual and auditory signals.

3. time of isolation Initially we plan to study two time patterns: a) 3 hours; b) 6 hours. Of course, other time patterns may occur in actual testing, since the subject is free to leave the tank at any time.

4. individual differences These will be measured differences in the subjects in terms of personality dimensions and physiological status.

Research Personnel

Donald G. Forgays, PhD, Principal Investigator
Wayne C. Patterson, PhD, Co-Investigator
Som N. Ghei, PhD, Consultant
Ernest D'Angelo, M.D., Medical Consultant
Richard Blanchard, M.E.E., Electronics Consultant
Joan Meyer, B.A., Graduate Research Assistant
Kenneth Marum, M.A., Graduate Research Assistant

Publications and Reports

1. Effects of Sensory Isolation Upon Psychological and Physiological Functioning: I.A Review of Selected Literature. In prepration for submission for publication. J. Nerv. Ment. Dis.

2. Effects of Sensory Isolation Upon Psychological and Physiological Functioning: II. Methodological Considerations. In preparation for submission for publication. J. Nerv. Ment. Dis.

3. Individual Differences in The Effects of Sensory Isolation. Paper read at the annual meeting of the Vermont Psychological Association, April 1966.

4. Effects of Sensory Isolation Upon Human Functioning. Paper read at the meetings of the XVIII International Congress of Psychology, Moscow, USSR, August 1966.